<u>Note No 1</u>: Delayed Neutron Time Constants and 6-group Fractions for n+^{237}U and γ+^{238}U

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After checking the following file of ENDF/B-VII beta1 available at
http://www.nndc.bnl.gov/csewg_members/

Photonuclear (163 materials, see **list** and 58 MB **gzip** file), released on Oct 24, 2005.

File : 157) 92-U -238 LANL EVAL-AUG05 M.GIACRI, D.RIDIKAS, M.CHADWICK 9237

"MT=455 - Delayed nubar taken from the ENDF/B-VI n+237U evaluation, 9237 1451 134
appropriately shifted to account for the neutron binding energy 9237 1451 135
and renormalized to match exp. data of Caldwell et al. [Ca75] 9237 1451 136
9237 1451 137"

we would like to pay your attention on important changes related to the 6-group delayed neutron time constants and fractions for n+^{237}U and γ+^{238}U. These changes concern the ENDF/B-VI.8 → ENDF/B-VII modifications as presented in Tables 1 and 2. The biggest difference is observed for the group 6 both in λ_6 and a_6 values (a factor of ~3), what results in $T_6 = \ln 2/\lambda_6 = 72.6$ ms being surprisingly short (typically around 200 ms as extracted from experiments).

Table 1: Delayed neutron time constants (in sec^{-1}) for n+^{237}U from different sources.

	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6
JENDL-3.3	1.3800-2	3.1600-2	1.2110-1	3.1620-1	9.0730-1	3.0368+0
ENDF/BVI.8	1.3762-2	3.1591-2	1.2107-1	3.1622-1	9.0731-1	3.0368+0
ENDF/B-VII	1.2496-2	3.0380-2	1.0690-1	3.2403-1	1.3343+0	9.5442+0

Table 2: Delayed neutron group fractions for n+^{237}U from different sources.

	a_1	a_2	a_3	a_4	a_5	a_6
JENDL-3.3	1.7841-2	1.47711-1	1.44459-1	3.86410-1	2.09517-1	9.40628-2
ENDF/BVI.8	1.7841-2	1.47711-1	1.44459-1	3.86410-1	2.09517-1	9.40628-2
ENDF/B-VII	1.5222-2	1.76926-1	1.47629-1	4.46292-1	1.77058-1	3.68734-2

As shown in Figures 1 to 3, the delayed neutron parameters adopted for γ+^{238}U in ENDF/B-VII cannot reproduce our recent experiment on photofission (see Fig. 1 in particular for short irradiation period, where the group 6 parameters are of the biggest importance). We also note that the "old" parameters from ENDF/B-VI.8 give reasonable reproduction of corresponding experimental decay curves.

Therefore, our recommendation is that for the time being for γ+^{238}U (and consequently for n+^{237}U) the "old" parameters from ENDF/B-VI.8 should be used. In the near future (after publication of our experimental results) we will be able to provide the new experimental values for γ+^{238}U (and consequently for n+^{237}U).

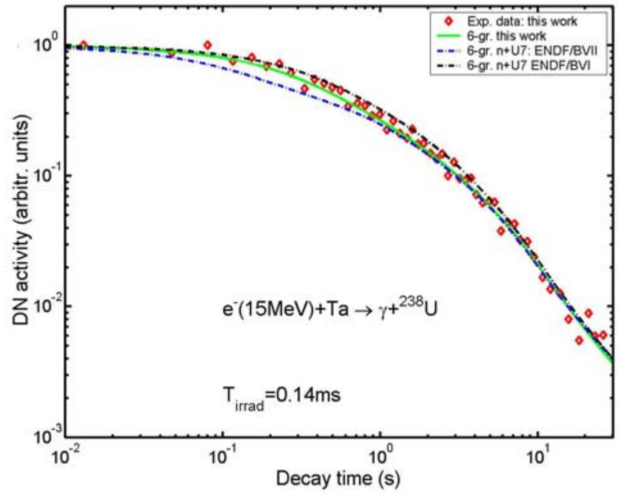

Figure 1: Delayed neutron activity vs. time after a short irradiation (0.14 ms); see the legend for details.

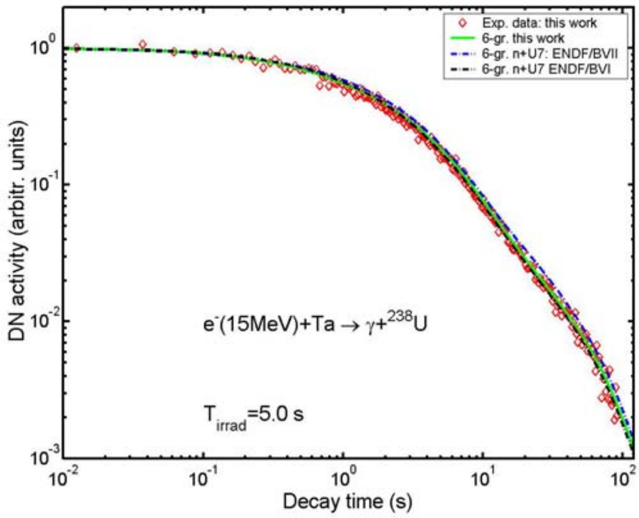

Figure 2: Delayed neutron activity vs. time after an intermediate irradiation (5.0 s); see the legend for details.

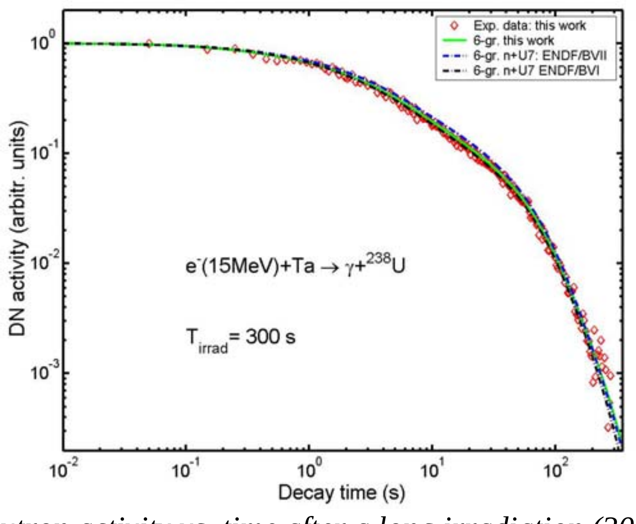

Figure 3: Delayed neutron activity vs. time after a long irradiation (300.0 s); see the legend for details.

<u>Note No 2:</u> Sensitivity of Delayed Neutron Calculations to 6-group Parameter Values and Irradiation Time

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This study is the continuation of our earlier work (see above) where we examine the delayed neutron 6-group parameters by comparing the modifications made from ENDF/B-VI.8 to ENDF/B-VII.b1. Note that here we only consider the *macroscopic 6-group parameters formalism* and will not discuss microscopic calculations based on fission product yield and decay data. The 6-group parameters (a_i, λ_i) used in this work are extracted directly from the corresponding ENDF files.

Delayed Neutron Activity

In the above part of this document, Figs. 1 to 3 display (in log-log scale) the *delayed neutron activity* (DNA) *vs.* cooling time (t) following three different irradiation times (T_{irr}),

$$DNA(T_{irr}, t) = \sum_i a_i e^{-\lambda_i t}\left(1 - e^{-\lambda_i T_{irr}}\right). \tag{1}$$

Fig. 4 (note the log-lin scale) shows similar calculations performed for various irradiation periods using either ENDF/B-VII.b1 or ENDF/B-VI.8 6-group parameter values for the same reaction n+^{237}U.

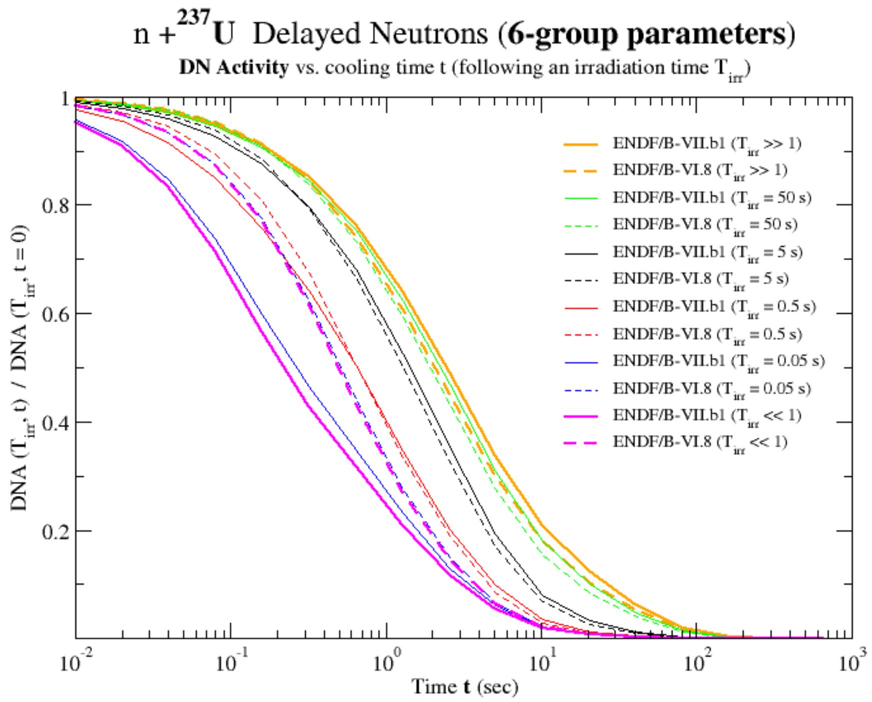

Figure 4: Comparison of delayed neutron activity vs. cooling time following various ^{237}U irradiation periods. Calculations are performed using ENDF/B-VII.b1 or ENDF/B-VI.8 6-group parameter values.

Fig. 4 clearly illustrates how the *delayed neutron activity* is linked to the irradiation length. Indeed, one observes a shift of the mean delayed neutron emission time to longer times following fission when the irradiation periods increase. Moreover, as already shown in Fig. 1, ENDF/B-VII.b1 and ENDF/B-VI.8 *delayed neutron activities* differ significantly for short irradiation times (see the magenta curves in Fig. 4). These differences are nearly invisible in the case of long irradiations (see yellow or green curves in the same Fig. 4). In the case of the actual short irradiation of 0.14 ms (see Fig. 1), ENDF/B-VI.8 better reproduces the *delayed neutron activity* following ^{238}U photofission.

Delayed Neutron Fraction

Instead of the *delayed neutron activity* (DNA), one considers now the number of delayed neutrons (DNN) emitted prior to cooling time t,

$$DNN(T_{irr},t)=\int_0^t N(T_{irr},x)dx=\sum_i a_i\left(1-e^{-\lambda_i T_{irr}}\right)\int_0^t e^{-\lambda_i x}dx=\sum_i a_i\frac{1}{\lambda_i}\left(1-e^{-\lambda_i t}\right)\left(1-e^{-\lambda_i T_{irr}}\right). \quad (2)$$

Fig. 5 shows the *delayed neutron fraction* emitted prior to the cooling time t, following various irradiation times (note the equivalency with Fig. 4).

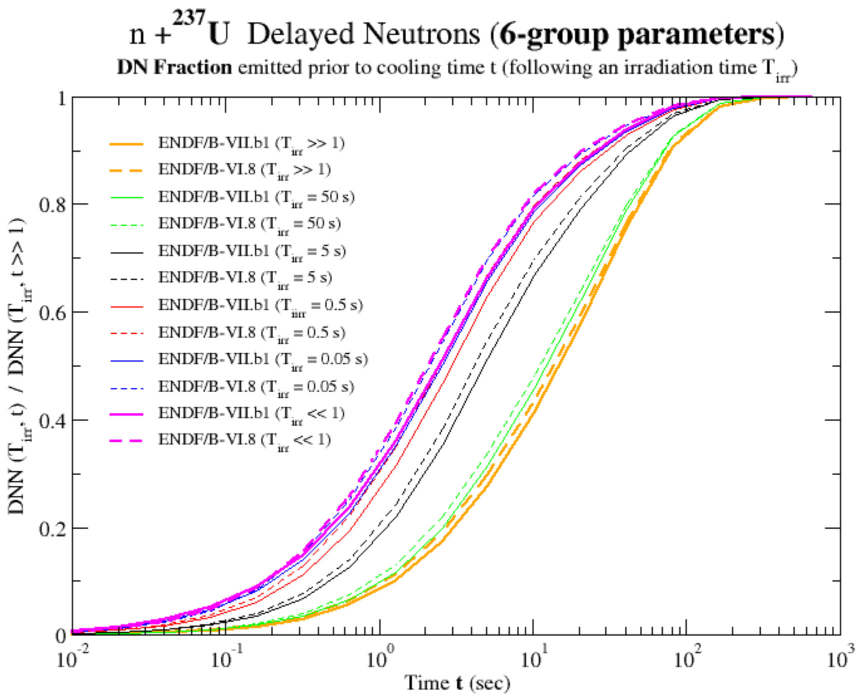

Figure 5: Comparison of the fractions of delayed neutrons emitted prior to cooling time t, following various ^{237}U irradiation periods. Calculations are performed using ENDF/B-VII.b1 or ENDF/B-VI.8 6-group parameter values.

Although Fig. 4 plots the *delayed neutron activity*, whereas Fig. 5 displays the *delayed neutron fraction*, both show a shift of the mean delayed neutron emission time to longer cooling times when the irradiation period is longer. **However, unlike the *delayed neutron activity* (Fig. 4), the *delayed neutron fraction* (Fig. 5) <u>is not sensitive</u> to the differences between some of the ENDF/B-VII.b1 and ENDF/B-VI.8 6-group parameters (i.e. differences in delayed neutron groups with short half-lives, simply due to the $1/\lambda_i$ factor in Equation 2).**

To confirm these observed above phenomena similar checks are done with other (more conventional) systems as $^{235}U(n,f)$ and $^{238}U(n,f)$ where delayed neutrons where measured both for short and long irradiation periods.

Other systems: $^{235}U(n,f)$ & $^{238}U(n,f)$

In the next pages, Figs. 6 to 7 show a similar comparison for delayed neutrons following ^{235}U fission, whereas Figs. 8 to 9 display results obtained for ^{238}U fission.

The experimental points plotted in Figs. 6 to 9 are calculated for two different irradiation periods using Keepin *et al.* 6-group parameters for ^{235}U thermal fission (Figs. 6 to 7) and for ^{238}U fast fission (Figs. 8 to 9) [*Phys. Rev.* **107** (1957) 1044].

As for $^{238}U(\gamma,f)$ data shown in Fig. 1, one observes for $^{235}U(n,f)$ and $^{238}U(n,f)$ a significant under-prediction of the *delayed neutron activity* for short irradiation times when using the new ENDF/B-VII.b1 6-group parameters (Figs. 6 and 8). Note that no conclusion can be drawn at the same time from *delayed neutron fraction* curves (Figs 7 and 9) since this quantity **is no/little sensitive to the 6th group values** (this group having the shortest half-life). Therefore, our suggestion is that delayed neutron activity should be a better observable in order to examine the delayed neutron parameters.

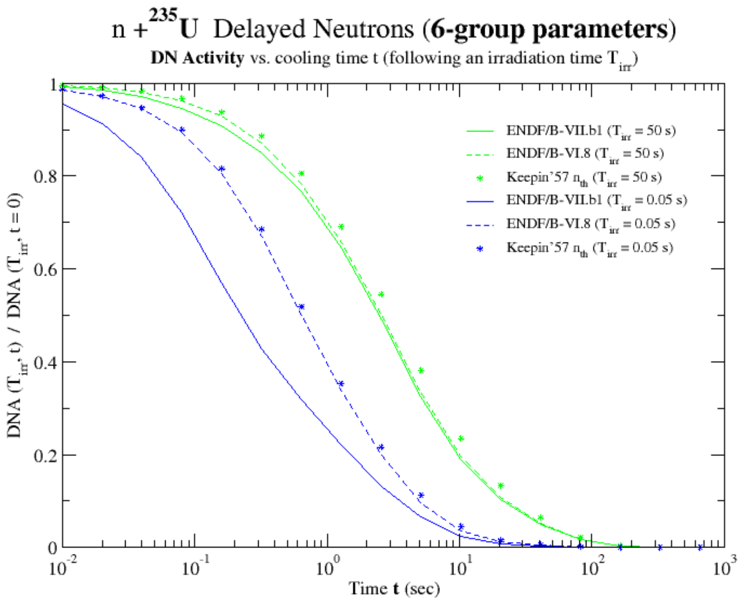

Figure 6: Comparison of delayed neutron activities vs. cooling time following ^{235}U fission.

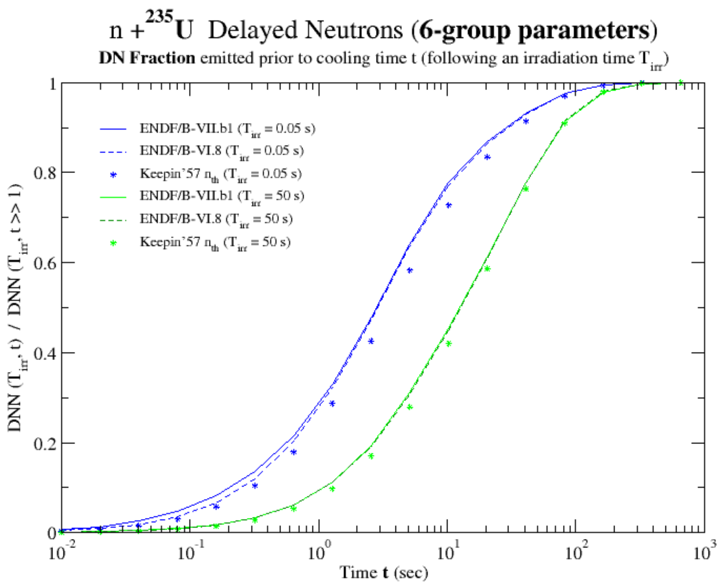

Figure 7: Comparison of delayed neutron fractions vs. cooling time following ^{235}U fission.

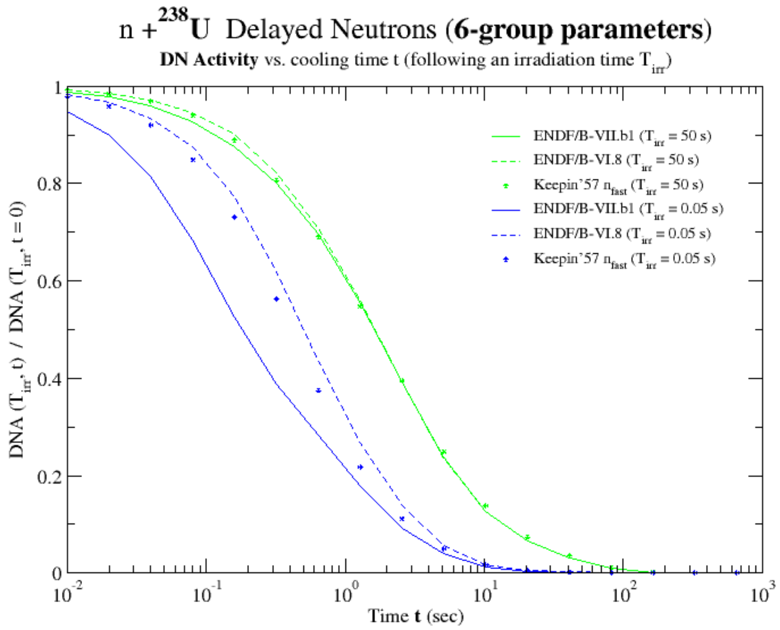

Figure 8: Comparison of delayed neutron activities vs. cooling time following ^{238}U fission.

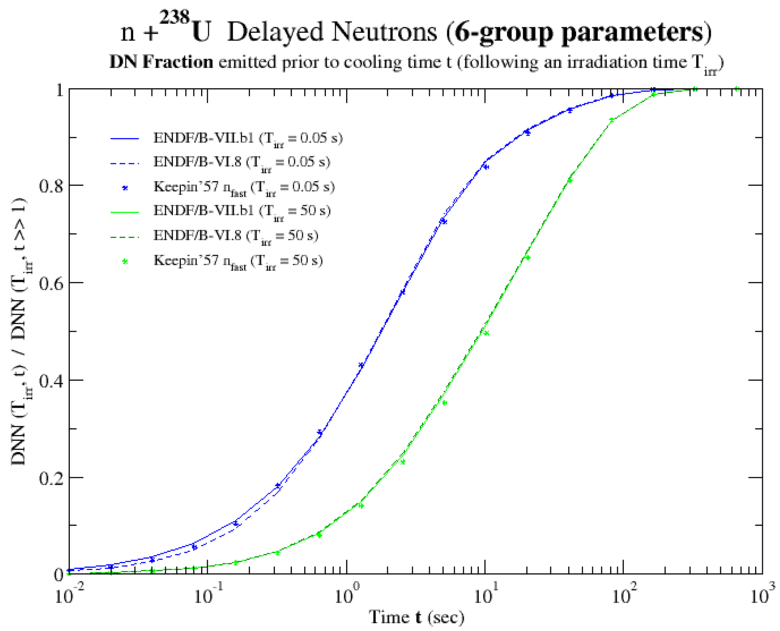

Figure 9: Comparison of delayed neutron fractions vs. cooling time following ^{238}U fission.